



APPENDIX C

Long-term Traffic Noise Monitoring Technical Memorandum

*For the C-470 Corridor
Revised Environmental Assessment*

November 2015

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COLORADO
Department of
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1.0 Introduction

During the C-470 Corridor Revised EA public review period, CDOT received multiple comments stating concern that CDOT had not collected long-term (i.e., 24-hour) (LT) noise measurements to validate the Traffic Noise Model (TNM) used to determine noise impacts and mitigation for the C-470 corridor. These public comments referenced the 2006 CDOT Traffic Noise Model User's Guide which states that *Long-term measurements provide a clear understanding of the loudest-hour noise level that repeats from day to day.*

While CDOT has maintained that the noise analysis conducted for the Revised EA included validation of the noise model consistent with the January 2015 CDOT Noise Analysis and Abatement Guidelines. CDOT understands the concerns raised by the public and therefore commissioned an effort to collect additional long-term (i.e., 24-hour) noise measurements and traffic data in October 2015 along the south side of C-470 between Quebec Street and University Boulevard. The purpose of collecting LT measurements, as described in CDOT's Traffic Noise Model User's Guide (2006), is to determine the loudest-hour noise levels and traffic volumes that repeat from day to day. These LT loudest-hour noise levels and traffic volumes may be used in conjunction with short-term field monitoring to validate the noise model.

1.1 Site Selection

The Highlands Ranch Neighborhood Coalition (HRNC), whose members submitted many of the comments related to long-term measurements, contracted Illingworth & Rodkin, Inc. (I&R), a noise consultant, to collect LT noise measurements in May 2015. I&R collected long-term field measurements at two locations. However, traffic data was not collected at the time of the long-term readings. CDOT selected two sites for long-term measurements within Highlands Ranch Metro District property, shown in Figure 1, CDOT LT-1 and CDOT LT-2, that were in close proximity to the previous I&R study locations. However, they were not in the exact locations as discussed below.

Figure 1 – Long-term Measurement Locations



CDOT LT-1 Site – LT-1 Site, shown in Figures 1 and 2, is north of 8568 and 8576 Meadow Creek Drive within Highlands Ranch Metro District property. This site was selected for long-term measurements based on the view of C-470, as seen in Figure 3, minimal potential for non-traffic noise generators (i.e., back yard play sets, dogs), and no solid fencing (split rail only) in the immediate area. The previous site selected for I&R LT-1 was not chosen due to the presence of a large dog barking in the immediate vicinity, roughly 30 feet from the monitoring location. Due to the proximity of this dog to the monitoring location, this would have a negative impact on the data and not be representative of the traffic noise conditions that are of value to collect for validation.

Figure 2 – CDOT LT-1 Measurement Location



Figure 3 – View of C-470 from CDOT LT-1 Site



CDOT LT-2 Site – CDOT LT-2 site, shown in Figure 4, is within Highlands Ranch Metro District property and approximately 90 feet west of the previous I&R LT-2. This site was selected for long-term measurements based on the proximity to I&R LT-2, limited opportunities for other locations adjacent to the Gleneagles golf course, minimal potential for non-traffic noise generators, (i.e., back yard play sets, dogs), and no solid fencing in the areas to reflect noise. The previous I&R LT-2 site was not selected because it was immediately adjacent to a solid wooden fence which has the potential to reflect noise and affect the noise levels of the traffic that are being collected. It should be noted that the parking area to the west of the site is associated with the future development of Shadow Canyon Condominiums and is not in active use at this time.

Figure 4 – LT-2 Measurement Location



1.2 Data Collection

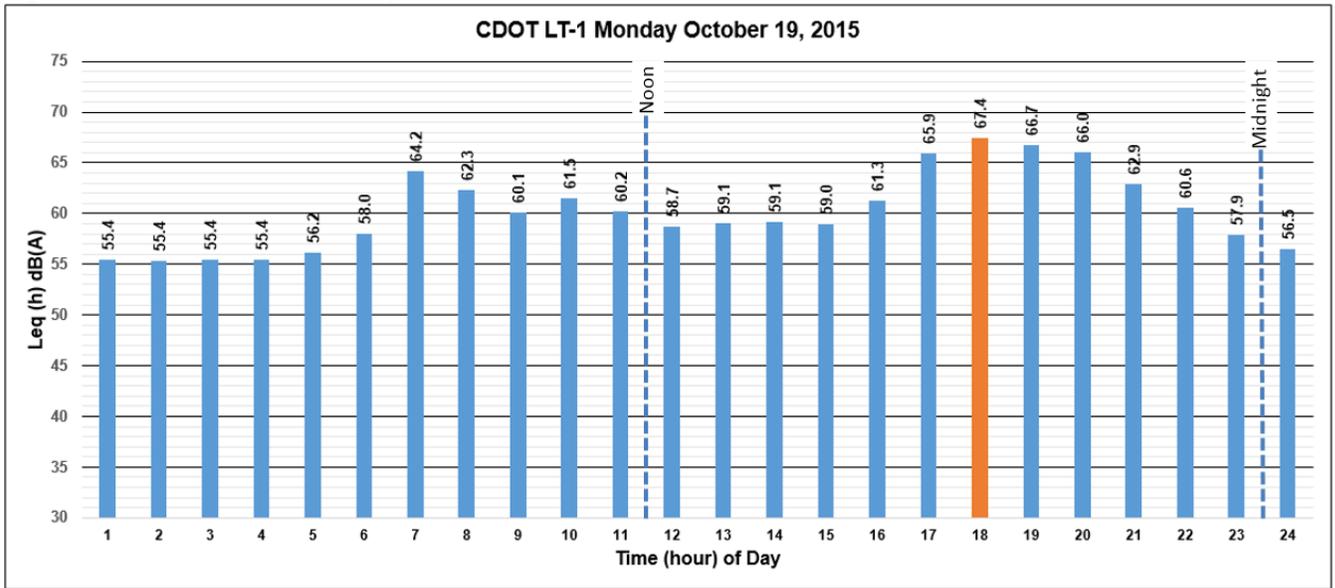
Field Measurements - Long-term (i.e., 24-hour) field measurements were collected with 3M™ SoundPro™ SE/DL Series Sound Level Meters SP-DL-2-1/3 in accordance with CDOT guidelines for four days between October 19, 2015 and October 30, 2015. The measurement periods were broken up over two weeks in an effort to avoid major weather fronts that were passing through the Highlands Ranch area which would void the collected data for that time period. It rained several times during these days which is why continuous monitoring in 1 week was not able to be completed. However it is not required that long term monitoring be taken all in one week or be continuous in order to validate a model.

The hourly Leq db(A) sound levels collected in the field at CDOT LT-1 and LT-2 are shown in Figures 5 through 12. The loudest valid hour for each period is shown in orange on each graph.

Traffic – Directional traffic volumes with vehicle classification data were collected during the measurement periods. Travel speeds were determined by traveling in the traffic stream during and around peak periods. Travel speeds ranged from stop conditions to 80 mph.

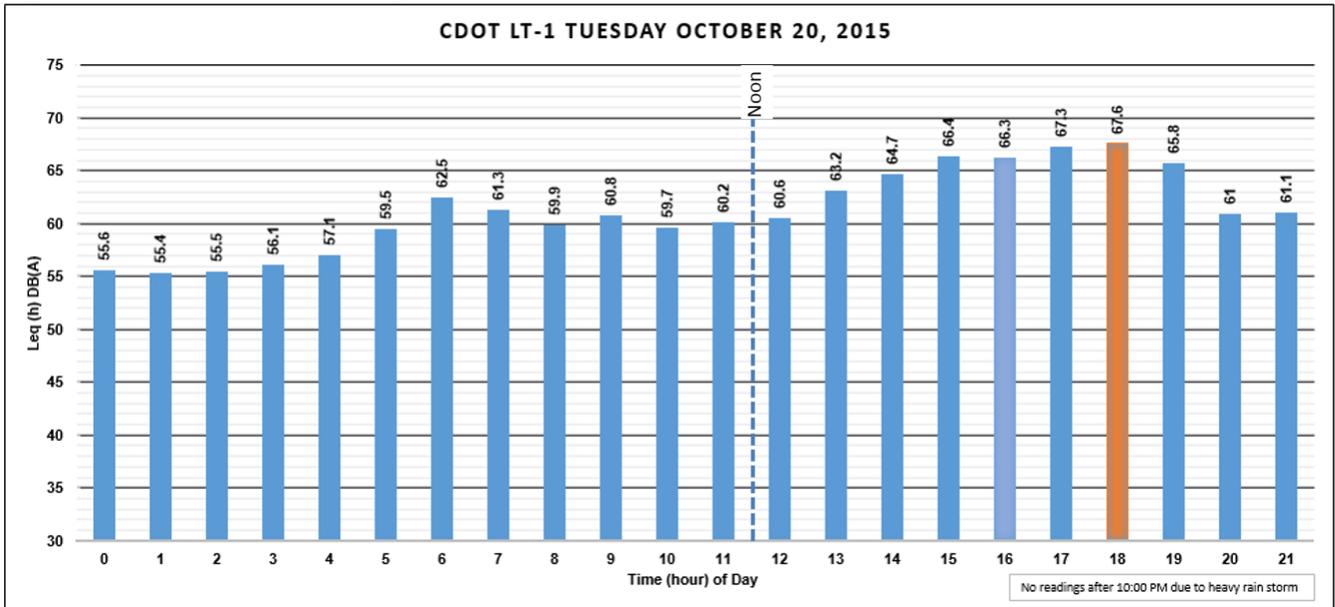
Meteorology – Temperature, wind speed and direction, humidity, and precipitation were collected using a Davies Vantage Pro 2 weather station. A three day storm event occurred October 21st through the 23rd. Data collection efforts were suspended during this period, as the data would not be considered valid.

Figure 5 – CDOT LT-1 Monday October 19, 2015



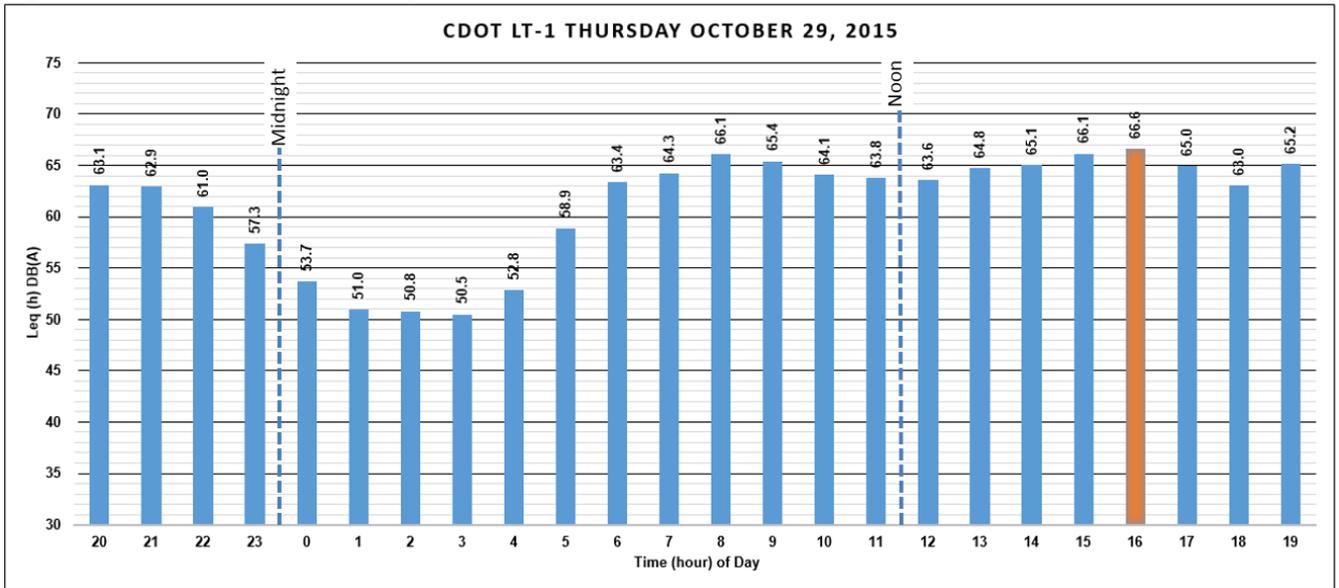
Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

Figure 6 – CDOT LT-1 Tuesday October 20, 2015



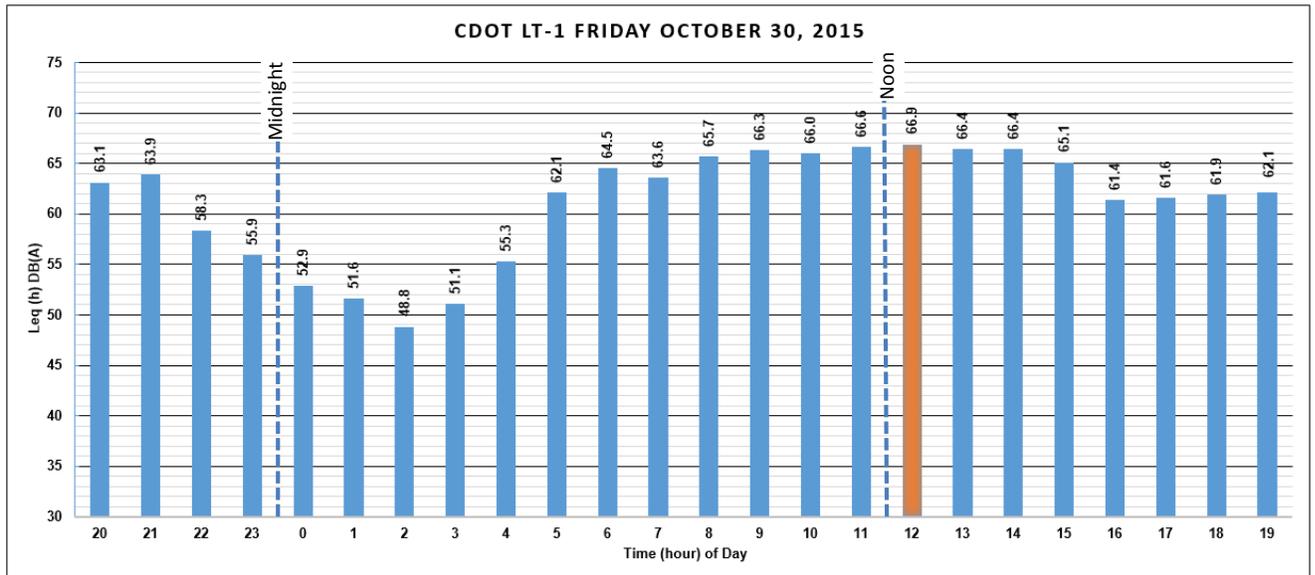
Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

Figure 7 – CDOT LT-1 Thursday October 29, 2015



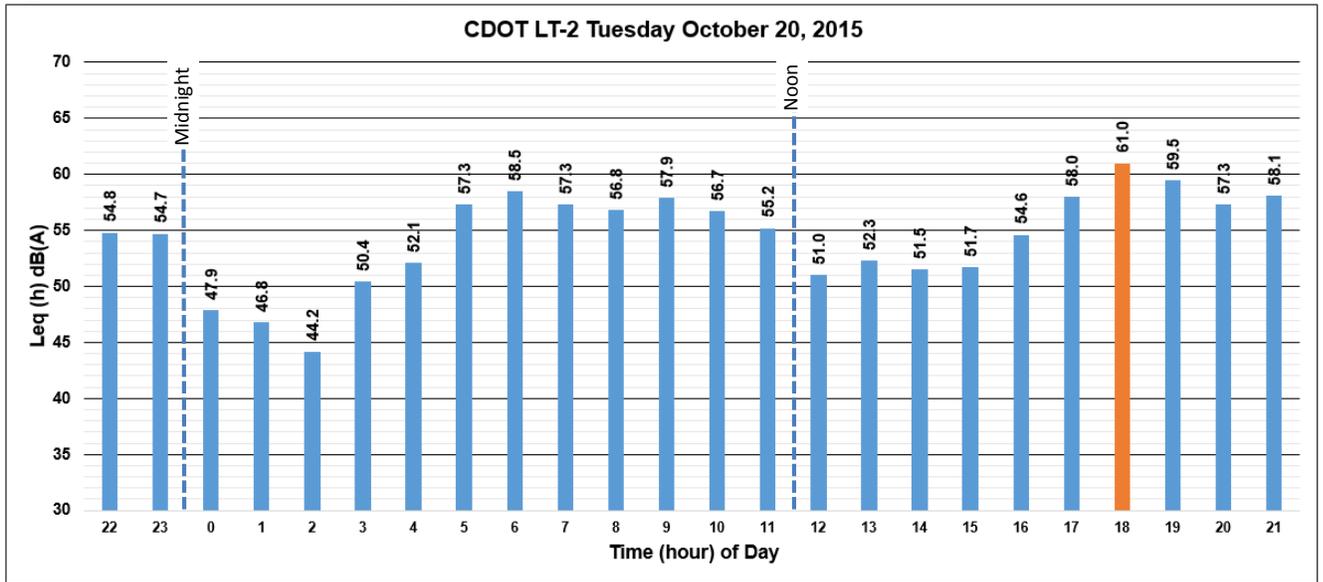
Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

Figure 8 – CDOT LT-1 Friday October 30, 2015



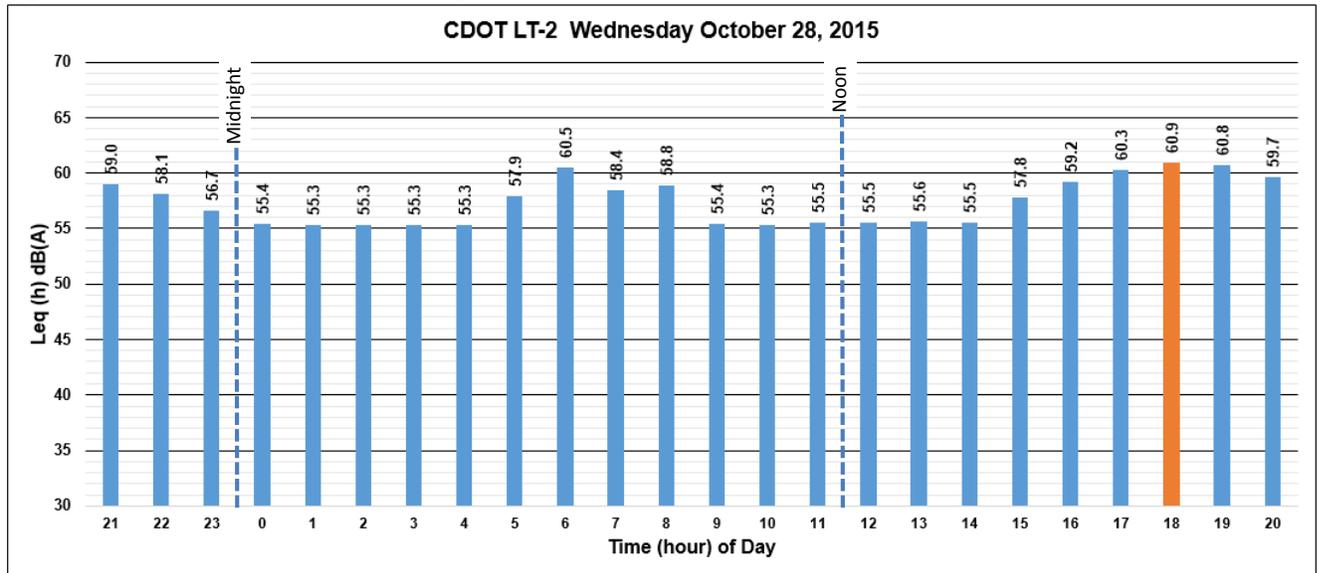
Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

Figure 9 – CDOT LT-2 Tuesday October 20, 2015



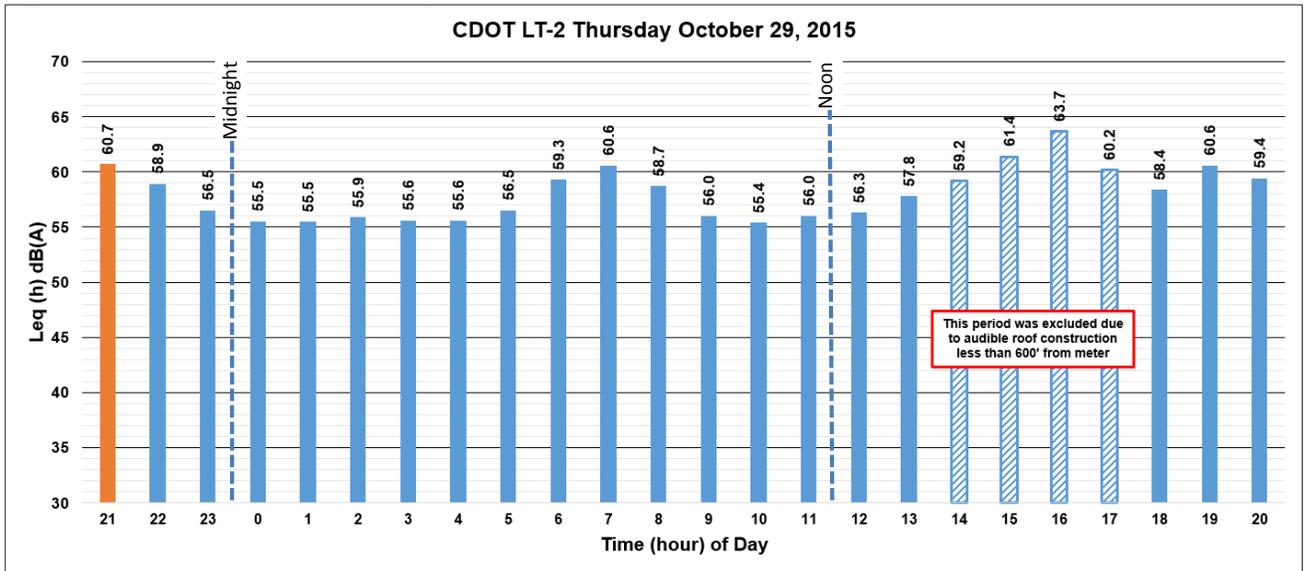
Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

Figure 10 – CDOT LT-2 Wednesday October 28, 2015



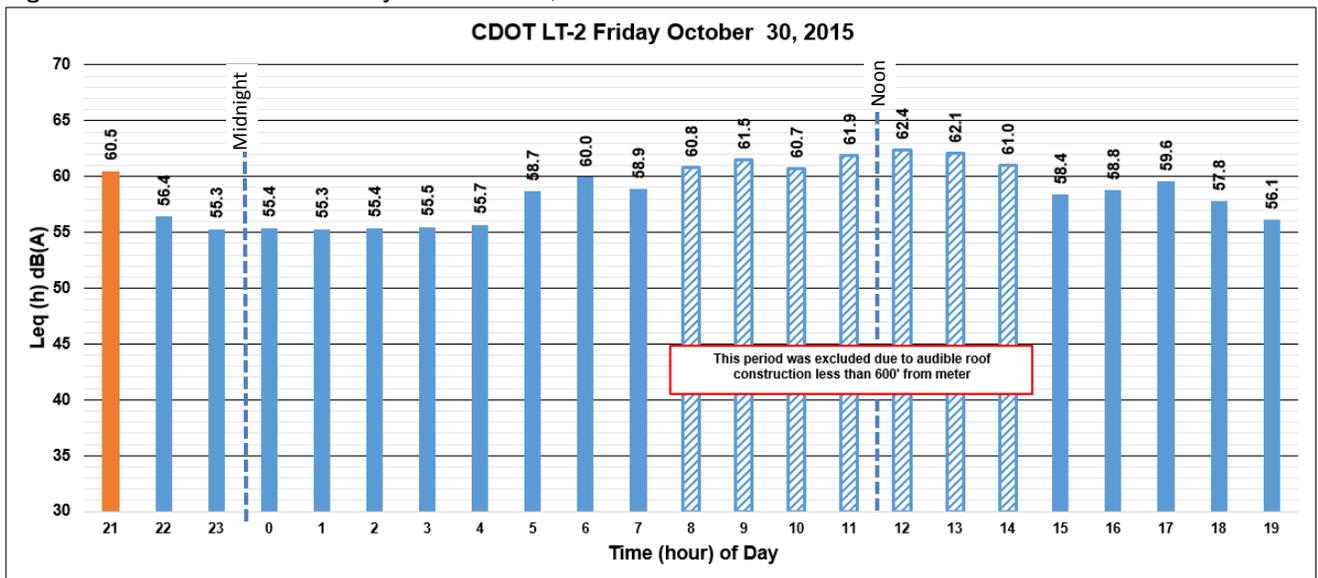
Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

Figure 11 – CDOT LT-2 Thursday October 29, 2015



Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

Figure 12 – CDOT LT-2 Friday October 30, 2015



Note: Orange bar indicates the highest hourly Leq during this monitoring interval.

1.3 Results

CDOT LT-1 - The loudest hours for LT-1, as shown in Figures 5 through 8, occurred between 6:00 PM and 7:00 PM daily except for Friday, October 30th, when traffic volumes peaked earlier in the day. Free flowing travel speeds during these loudest-hours ranged from 70 to 75 mph. The loudest hourly Leq of 67.6 dB(A) for CDOT LT-1 occurred on Tuesday October 20th from 6:00 PM to 7:00 PM. Traffic data for this period is shown in Table 1.

Table 1 – CDOT LT-1 Loudest-hour Traffic

6-7:00 PM Oct 20th	Auto	Medium Trucks	Heavy Trucks	Buses	Motorcycles	Total	Speed (mph)
WB	3,752	21	10	1	4	3,788	70-75
EB	3,152	48	6	2	8	3,216	
Total	6904	69	16	3	12	7,014	

To verify the TNM model's ability to replicate this existing loudest-hour sound level, a receptor was placed in the Existing 2013/2015 TNM model at the LT-1 location and the traffic data collected in the field, shown in Table 1, was used for C-470 travel lanes. No other changes were made to the Existing 2013/2015 TNM model. The results are shown in Table 2.

Table 2 – Comparison of Field Measurements and Model Results at Varying Speeds

Loudest Long-Term Field Measurement dB(A)	TNM Model Results at 70 mph dB(A)	Difference
67.6	65.8	-1.8
Loudest Long-Term Field Measurement dB(A)	TNM Model Results at 75 mph dB(A)	Difference
67.6	66.7	-0.9

CDOT LT-2 - The loudest hours for LT-2, as shown in Figures 9 through 12, also occurred between 6:00 PM and 7:00 PM daily. The loudest hourly Leq of 61.0 dB(A) occurring on Tuesday, October 20th, from 6:00 PM to 7:00 PM. Free flowing travel speeds during this loudest-hour ranged from 70 to 75 mph. The traffic data for this period, which is the same period as the loudest-hour for LT-1, is shown in Table 1. As discussed previously, both LT-1 and LT-2 are located south of C-470 between Quebec Street and University Boulevard. There are no on or off-ramps in this stretch of C-470. Thus, hourly traffic volumes are the same for these locations.

The data collection sites were visited multiple times each day by a noise professional. On Thursday, October 29th and Friday, October 30th a 5 dB(A) increase in peak and Leq(h) sound levels were observed on the sound meter. These increases were related to roof construction observed at a home on Whimbrel Drive, approximately 600 feet from the site. The construction work was visible, with a direct line-of-sight, from the sound meter and clearly audible at the sound meter. These non-traffic related noise events occurred from 2 PM to 5 PM on Thursday, October 29th and from 8 PM to 2 PM on Friday, October 30th. The effects of these events is evident by comparing the sound levels in Figures 9 through 12. As a result of these non-traffic related noise events, those periods were excluded from the analysis.

To verify the TNM model's ability to replicate the existing loudest-hour sound levels, a receptor was placed in the Existing 2013/2015 TNM model at the LT-2 location and the traffic data collected in the field, shown in Table 1, was used for C-470 travel lanes. No other changes were made to the Existing 2013/2015 TNM model. The results are shown in Table 3.

Table 3 – Comparison of Field Measurements and Model Results at Varying Speeds

Loudest Long-Term Field Measurement dB(A)	TNM Model Results with C-470 at 70 mph dB(A)	Difference
61.0	60.6	-0.4
Loudest Long-Term Field Measurement dB(A)	TNM Model Results with C-470 at 75 mph dB(A)	Difference
61.0	61.5	+0.5

1.4 Conclusions

- The four days of 24-hour sound level measurements along with associated traffic data satisfies the recommendations of the 2006 TNM Users Guide for determining loudest hour to be used in validation of the noise model.
- The TNM model results presented in Tables 2 and 3 are within the acceptable range per guidance [3 dB(A)] of the LT field readings and thus the TNM model is considered to be validated. The validated TNM model can be used to accurately predict existing and future worst-noise levels for these areas.
- CDOT guidance requires that **actual** traffic volumes, travel speeds, and sound levels from field monitoring be used in the validation process. However, it should be noted that for all impacts and mitigation analyses, guidance requires that the existing and future models used to predict noise levels must use the **posted** travel speeds, expecting that traffic laws will be followed. The difference between actual travel speed for validating the model (70-75 mph) and posted travel speed (65 mph) explains why the loudest hour field measurements at the two collection locations are higher than the model-predicted existing noise levels presented in the July 2015 Traffic Noise Technical Report.
- A comparison of the LT loudest-hour traffic volumes collected in the field with the model volumes, presented in Table 4, demonstrates that CDOT used a conservative loudest hour traffic volumes for the Revised EA impact and mitigation analysis. The October 2015 loudest-hour traffic volumes of 7,014 vehicles equates to an average of 1,754 vehicles per lane for the two eastbound and westbound lanes. For CDOT's existing and 2035 traffic models, a total of 1,800 vehicles per lane, eastbound and westbound, were used based on suggested maximum traffic volumes for worst noise hour presented in Exhibit 4 of the Noise Analysis and Abatement Guidelines. Additionally, the fleet composition assumed in CDOT's modeling uses higher percentages of louder vehicle classes (e.g., heavy trucks and buses) than were observed in the October 2015 loudest-hour. Thus, fleet composition is another aspect where CDOT's modeling is conservative.

- The LT traffic noise monitoring efforts presented in this memorandum have confirmed the methodologies used and validation of the TNM model for the C-470 Revised EA. No changes to the C-470 Traffic Noise Technical Report are warranted at this time.

Table 4 – Comparison of Traffic Volumes

	Total	Auto	Medium Trucks	Heavy Trucks	Buses	Motorcycles
Long-term Measurement Field Data 6-7:00 PM Oct 20th	7,014	6,904	69	16	3	12
TNM Model Volumes used for existing impact	7,200*	6,964**	144**	72**	8**	8**
Percentage of Model vs Field Volumes	102.7%	100.9%	208.7%	450%	266.7%	66.7%

* Reflects 1,800 per lane for all 4 lanes, which represents the most traffic possible travelling at posted speed for this type of highway facility per *Exhibit 4. Suggested Maximum Traffic Volumes for Worst Noise Hour* of the January 2015 CDOT Noise Analysis and Abatement Guidelines

** Vehicle classification percentages were based on actual traffic counts collected in the corridor in July 2014.